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Accuracy comparison of accounting-based bankruptcy prediction models of Springate (1978), Ohlson (1980) and Altman (2000) to US manufacturing companies 1990-2018

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Abstract

The importance of corporate bankruptcy has risen to ever more prominence since the recent financial crisis. The field of bankruptcy prediction has become even more popular among academics and is considered to be an industry itself. It is estimated that at least 40,000 people are dealing with corporate distress. The estimation of bankruptcy is intriguing but still a bankruptcy prediction model with high accuracy rate remains a challenge since the models are based on certain industries and tend to be sample specific.

Recently, market-based bankruptcy prediction models have gained popularity among researchers in the field, however, there is no supportive evidence of their superiority compared to accounting-based models that aim to predict financial distress using financial accounting data. Although new complex models e.g. neural network techniques have emerged to the literature, the accounting-based techniques are still most popular in the research.

This paper attempts to add finding to the literature by comparing three accounting-based bankruptcy prediction models of Altman (2000), Ohlson (1980) and Springate (1978) in order to present comprehensive computational comparison of methodologies to fulfil the strategic information needs of investors and other stakeholders. The aim is to statistically show that the models differ in accuracy rates in US manufacturing industry. The sample of the study consists of thirty-three bankrupt and 414 non-bankrupt United States manufacturing companies that were listed in either NYSE, Nasdaq or American Stock Exchange in 1990-2018.

The result of one, two and three years prior to bankruptcy indicates that the three accounting-based bankruptcy prediction models of Altman (2000), Ohlson (1980) and Springate (1978) have different predicting power to bankruptcy in US manufacturing companies. Furthermore, the results show that the Altman´s (2000) model performs better than the models of Ohlson (1980) and Springate (1978) when predicting bankruptcy in US manufacturing companies but the differences in the accuracy rates are all not statistically significant.

Keywords: Financial distress prediction; bankruptcy prediction model; Altman model; Ohlson model; Springate model; Logistic regression analysis; Multivariate discriminant analysis

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Tiivistelmä

Yrityksen konkurssin merkitys on noussut yhä enemmän esiin viimeisestä finanssikriisistä lähtien. Konkurssin ennustaminen on yhä suositumpi tieteen ala akateemikoiden keskuudessa ja sitä voidaan jo pitää omana merkittävänä tieteensuuntauksena. Konkurssien parissa arvioidaan työskentelevän maailmanlaajuisesti jopa 40,000 ihmisen. Konkurssin ennustaminen on kiehtovaa, mutta edelleen on haasteena kehittää malli, jonka ennustuskyky olisi korkea myös alkuperäisen aineiston ulkopuolelle sovellettaessa.

Viime aikoina myös markkinadataan perustuvat ennustamismallit ovat saavuttaneet suosiota tutkijoiden keskuudessa, mutta toistaiseksi ei ole löytynyt tukea mallien paremmuudelle tilinpäätösdataan perustuviin malleihin nähden. Vaikka kirjallisuudessa on ilmennyt uusia monimutkaisia malleja, esimerkiksi hermoverkkoihin perustuvat tekniikat, ovat tilinpäätösdataan perustuvat mallit edelleen suosituimpia kirjallisuudessa.

Tämän tutkimuksen tavoitteena on kolmea tilinpäätösdataan perustuvaa konkurssin ennustamismallia vertailemalla, jotka ovat Altmanin (2000), Ohlsonin (1980) ja Springaten (1978) malli, tarjota laskennallista dataa, jota sijoittajat ja yrityksen muut sidosryhmät voivat hyödyntää teollisuusalan yritysten konkurssin todennäköisyyttä arvioidessaan. Tutkimuksen otos koostuu 33 konkurssiin menneestä ja 414 terveestä Yhdysvaltalaisesta teollisuusyrityksestä, jotka olivat vuosien 1990-2018 aikana listattuna joko NYSE:en NASDAQ:iin tai American Stock Exchange:en.

Tulokset yhtä, kahta ja kolmea vuotta ennen konkurssia osoittavat, että Altmanin (2000), Ohlsonin (1980) ja Springaten (1978) tilinpäätösdataan perustuvissa ennustusmalleissa on erilaiset ennustusvalmiudet yhdysvaltalaisissa teollisuudenalan yrityksissä. Lisäksi tulokset osoittavat, että Altmanin (2000) malli toimii paremmin kuin Ohlsonin (1980) ja Springaten (1978) mallit, mutta erot ennustustarkkuudessa eivät kaikki ole tilastollisesti merkitseviä.

Keywords: Konkurssin ennustaminen; konkurssin ennustamismalli; Altmanin malli; Ohlsonin malli; Springaten malli; Logistinen regressioanalyysi; MDA

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1. INTRODUCTION

1.1. Backround

The recent financial crisis that caused severe economic challenges for the global economy have renewed the interest towards the default risk literature and default risk prediction. Another boost for the credit risk assessment have been the new requirements of Basel II and the explosive growth of the credit derivatives market (Agarwal and Taffler, 2008). A dozen of bankruptcy models have been suggested by the researchers to predict bankruptcy, such as discriminant analysis (Beaver, 1966; Altman, 1968), logit and probit models (Ohlson, 1980; Charitou et al., 2004; Jones and Hensher, 2007), artificial neural networks (Wilson and Sharda, 1994; Serrano, Cinca, 1997; Charalambous et al., 2000) and survival analysis (Luoma and Laitinen, 1991; Shumway, 2001). The aim of these models is to predict business failure and to classify firms according to their financial health. Despite the great amount and variety of bankruptcy prediction models, no single model has been able to outperform the others in general.

Two main periods of bankruptcy prediction models can be found in the previous literature. The first is a period from late 1960´s to the late 1980´s and is characterized by models that relied greatly on discriminant analysis and logistic regression. The studies of Altman (1968) and Ohlson (1980) are among the most famous studies of the era. The models of the first era have quite a few drawbacks such as the input-output variables dependency which means the dependency between the financial ratios as explanatory variances and the probability of bankruptcy.

The second period from late 1980´s is, on the other hand, characterized by new modeling techniques like non-parametric methods and non-linear techniques such as neural networks. The motivation behind these methods is to overcome the shortages and limitations of the methods of the first period.

The current study test three well known accounting-based bankruptcy prediction models for US manufacturing companies with financial data spanning from 1990 to 2018. These three accounting-based bankruptcy prediction models are the Altman (2000), Springate (1978) and Ohlson (1980) model. A substantial literature on bankruptcy has emerged since Beaver´s (1966) and Altman´s (1968) classic studies. Three most notable and cited accounting-based bankruptcy models in the accounting research literature are Altman (1968), Ohlson (1980) and Zmijewski (1984) (Grice and Dugan, 2001). In this study, the Zmijewski´s model wasn´t selected since its predictive power was relatively low compared to other models when adapted to US manufacturing companies. The variables and statistical techniques of the models of this study differ and therefore their predictive power or accuracy can be assumed to differ. Hence, it is interesting to see which combination of variables (i.e. model) works best for the manufacturing industry. Also, time has changed since these models were created and the question whether they are still suitable and perform well in predicting financial distress is intriguing. This study compares the performance of the three classic models to determine which performs best in the US manufacturing companies in time span from 1990 to 2018. The models were chosen based on their popularity in previous literature and on the basis of their predictive power in the initial sample of the study.

1.2. Objective

This study aims to analyze the accuracy of the model of Altman (2000), Springate (1978) and Ohlson (1980) in predicting financial distress in US manufacturing companies. This objective is achieved by comparing the results of each model t-1, t-2 and t-3 (years prior to bankruptcy). The goal is to find out if there are differences between the different bankruptcy prediction models and which model performs best in manufacturing industry.

1.3. Research Questions

The focus of this study will be on determining the best suitable accounting-based bankruptcy model for US manufacturing companies by comparing three accounting-based models from previous literature. In order to assess the performance of these bankruptcy prediction models, finding out which one to use and measuring the accuracy rate of them is crucial. The higher the accuracy rate of a model, the less error it will have in classifying the companies. The leading research questions of the Thesis is:

What is the difference in predictive power of accounting-based bankruptcy prediction models of Altman (2000), Ohlson (1980) and Springate (1978) to listed US manufacturing companies 1990-2018?

1.4. Justification

The topic of bankruptcy has been in interest of many since the financial crisis and its more important than ever to test the ability of the models in practice. Furthermore, it's interesting to see how well the traditional accounting-based bankruptcy prediction models can predict financial distress in today´s economy. Also, the applicability of the models to different countries and samples is important as it shows whether they can be applied as such to other settings or not.

Numerous studies since Beaver´s classic study (1966) have tried to analyze and compare the predictive power or the accuracy of the accounting-based bankruptcy prediction models. Usually in these studies the samples differ geographically and by industry and in the interest of the researcher is to evaluate whether a model is suitable for certain country or industry by examining its accuracy rate. Examples of such studies are the study of Kleinert (2014), Yelkenci (2015), Xu (2018) and Gerritsen (2015). The main purpose of these studies is to recognize the distress, or even the failure, in advance, so the contribution is on the "obvious practical interest" as indicated by Ohlson (1980). However, there hasn´t been a single study to test the three bankruptcy prediction models presented in this study in US manufacturing companies. The aim of this study is to find out the accuracy rate of three accounting-based bankruptcy models of Altman (2000), Ohlson (1980) and Springate (1978) using listed US manufacturing companies during 1990-2018.

This research contributes to the bankruptcy literature and research by providing evidence that different accounting-based models have different predicting power in US manufacturing companies. Numerous studies have been made to analyze bankruptcy prediction models, however, in any of those the three models compared in this study haven´t been tested for US manufacturing companies. Investors evaluating the likelihood of failure in manufacturing industry in United States can benefit from this study since it clearly demonstrates how well the different commonly used accounting-based models function in US manufacturing industry. Also, other stakeholders of a company will benefit from the study as they have better understanding of how bankrupt can be predicted and better understanding of the financials behind the possible failure.

1.5. Outline

An outline of this paper is as follows. Section 2 reviews the existing literature on bankruptcy prediction models. The focus is on the models used to predict financial distress in this study. The original methodology used to estimate the models of Altman (2000), Springate (1978) and Ohlson (1980) is examined and analyzed. Section 3 presents the research method and data of this study. The results and the discussion of these results are reported in section 4. The paper ends with conclusion and suggestion for further research.

2 SURVEY OF LITERATURE

In order to provide an overview of the development of research within the bankruptcy prediction literature, a description of the two major streams of research is included in this section: accounting-based bankruptcy prediction models i.e. models based on accounting information and market-based models i.e. models using market prices. However, the primary focus is on research of accounting-based models and the three models used in this study to predict financial distress.

2.1. Terminology and Definitions

The unsuccessful business enterprise has been defined in numerous ways in attempts to depict the formal process confronting the firm and/or to categorize the economic problems involved. Karles and Prakash (1987) discussed the concept of bankruptcy and clarified that "bankruptcy is a process which begins financially and is consummated legally". In many studies, the term *failure* is used as a legal definition of bankruptcy (e.g. Charitou et al., 2014, Altman 1968). Failure, by economic criteria, means that the realized rate of return on invested capital, with allowances for risk consideration, is significantly and continually lower than prevailing rates on similar investments (Altman and Hotchkiss, 2006).

The precise moment when bankruptcy occurs is difficult to discern. From the financial point of view a diverse set of definitions have emerged to explain failure. These include: negative net worth, non-payment of creditors, bond defaults, inability to pay debts, over-drawn bank accounts, omission of preferred dividends, receivership, etc. In the short term, a firm can continue its operations even though exemplifying these traits (Karles and Prakash, 1987).

Also, the terms *default*, *insolvency* and *bankruptcy* are commonly found in the literature. Defaults can be categorized to technical and/or legal. Technical default is a situation where the debtor violates a condition of an agreement with its creditor. Examples are violation of a loan covenant such as equity or debt ratio. Usually, these violations can be renegotiated because the purpose of such covenants is to signal deflating firm performance. A legal default can occur when a firm misses a scheduled loan or bond payment. In such a case, the firm may continue to operate, however it has to work out a distressed restructuring with its creditors to avoid formal bankruptcy declaration and filing. Insolvency and bankruptcy are linked as the latter is a more critical sense of insolvency and is characterized by chronic condition. Insolvency may be a temporary condition and as such the firm may be able to continue if its cash flows improves so that it can cope with its short-term debt obligations (Altman and Hotchkiss 2006).

2.2. Bankruptcy prediction models

Two major group of models can be found in the existing literature: accounting-based bankruptcy prediction models and market-based bankruptcy prediction models (Agarwal and Taffler, 2008). The accounting-based models use the accounting data of companies to predict financial distress. The market-based models also use accounting data but include data from market i.e. interest rates, shares and macroeconomic variables. Next, the two type of models are discussed more in-depth.

2.3. Accounting-based bankruptcy prediction models

With few exceptions, the literature of bankruptcy prediction has relied on accounting-based measures as the predictor variables (Hillegeist et al., 2004). The accounting-based models use the financial information of a company to assess the risk of a failure of a company. Usually this information is in the form of financial ratio´s that can be categorized into four categories: 1) profitability ratios, 2) liquidity ratios, 3) financial leverage (long-term solvency) ratios, 4) efficiency (turnover or activity) ratios (Lev, 1974). The accounting-based bankruptcy prediction models use either single financial ratio or a group of ratios (multivariate model) to predict financial distress. The use of single ratio analysis i.e. traditional ratio analysis has its limitations. According to Altman (1968) “Ratio analysis presented in this fashion is susceptible to faulty interpretation and is potentially confusing. For instance, a firm with a poor profitability and/or solvency record may be regarded as a potential bankrupt. However, because of its above average liquidity, the situation may not be considered serious. The potential ambiguity as to the relative performance of several firms is clearly evident. The crux of the shortcomings inherent in any univariate analysis lies therein.” The use of traditional ratio analysis hasn´t gain much popularity in the literature due to its obvious shortcomings as demonstrated by Altman (1968).

The use of financial statement data in investigating the relationship between failed and non-failed firms started in the early 1930´s, when Fitzpatrick (1931) and Merwin (1942) studied the phenomenon of bankruptcy. The most revolutionary studies in the field were published in the late 1960´s by Beaver (1966) and Altman (1968). Altman was the first to use a multivariate discriminant analysis (MDA) in predicting business failure. Since then the use of financial ratios to predict failure has been a topic of much interest in accounting and finance. Ohlson (1980) and Zmijewski (1984) are among other notable studies since Beaver and Altman breakthrough in this field of research. The use of financial ratios to predict financial distress can be justified on their basis of ex-hypothetical capability to indicate the financial soundness or sickness of a company and on the basis of their proven in earlier studies (Yadav, 1986).

On the other hand, accounting-based models have their limitations. Most importantly, they tend to be sample specific. According to Agarwal and Taffler (2008) accounting-ratio based models are typically built by searching through a large number of accounting ratios with the ratio weightings estimated on a sample of failed and non-failed firms. Since the ratios and their weightings are derived from sample analysis, such models are likely to be sample specific. Another important deficiency of accounting-based bankruptcy prediction models is their failure to incorporate a measure of asset volatility. Volatility is a crucial variable in bankruptcy prediction because it captures the likelihood that the value of the firm’s assets will decline to such an extent that the firm will be unable to repay its debts. Ceteris paribus, the probability of bankruptcy is increasing with volatility (Hillegeist et al., 2004).

It is evident that much past research has employed relatively small samples of firms. This inherent difficulty should not impede future research but it may lead researchers away from methodologies where large samples are critically necessary. It may also be worthwhile to include corporate governance structure in addition to financial ratios that have been dominant in most research to date (Aziz and Humayon, 2006).

2.3.1 Altman (1968, 2000)

Admittedly, the most famous bankruptcy prediction model is Edward I. Altman´s Z-Score that was published in 1968 just two years after Beaver´s (1966) study. The objective of the study was to find out which combinations of financial ratios predict bankruptcies best. Altman collected data from 66 publicly held manufacturing companies in the USA between 1946 and 1965. Altman (1968) used the model validation technique called 'cross-validation' to validate his function. This technique is used for assessing how the results of a statistical analysis will generalize to an independent data set and it's commonly used where the goal is prediction (Kohavi, 1995). Noteworthy the variables that worked best as a group weren´t necessarily effective when measured independently. Altman chose the variables on the basis of their popularity in the previous literature and potential relevance to the study (Altman, 1968).

The constructed discriminant function, the Z-Score, with the independent variables (A, B…E) and discriminant coefficients (1.2,1. 4…1.0) is as follows:

$$\text{Z-Score} = 1.2A + 1.4B + 3.3C + 0.6D + 1.0E \qquad \text{(e.g. 1)}$$

Where:
A = working capital / total assets
B = retained earnings / total assets
C = earnings before interest and tax / total assets
D = market value of equity / total liabilities
E = sales / total assets

To interpret the results of a Z-Score, Altman used a classification scale. A "grey area" is between 1.81 and 2.99 and firms with z-scores within this range are considered uncertain about credit risk and considered marginal cases to be watched with attention. Z- Score below 1.81 indicate a failed firm. The cut-off point was set to 2.675, however, Altman advocates using the lower bound of the "grey area" as more realistic cut-off score (Altman, 1968).
Altman has since revisited the model in multiple occasions. He has provided models for

extensively for non-manufacturers & emerging market (Altman 2000) and for private firms (Altman 2000). The accuracy rate of the models was quite same as the original model.

Various researchers have criticized Altman´s (1968) work based on lack of evidence of ex ante predictive ability of ratios (Joy and Tollefson, 1975; Moyer, 1977). According to Moyer (1977) better explanatory power could be obtained if market values of equity/book value of debt and sales/total assets variables were eliminated. Although studies that used Altman´s Z-Score model are mainly positive there is criticism towards his work. The main criticism is based on (1) the age of the original Altman (1968) model and (2) on the research design of the models namely, 33 bankrupt and 33 non-bankrupt firms (Boritz et al., 2007 and Grice and Ingram, 2001). Van Dalen (1979) proposes to use proportional samples to improve the representativeness of the samples. Second, only manufacturing firms are used as the sample for the study (Grice and Ingram, 2001). This limits the generalizability of the results because other industries are excluded. Finally, Altman chose the variables based on the previous literature not on theoretical basis.

2.3.2 Springate (1978)

The Springate (1978) model was introduced by Gordon L. V. Springate in 1978. Similarly, to Altman and Zmijewski, Springate (1978) used multiple discriminant analysis (MDA) methods to select 4 ratios out of 19 financial ratios that are the best predictors of the financial distress. These were the financial ratios that best distinguished between sound business and those that actually failed. Springate (1978) modified Altman´s MDA formula for Canadian use and reached an accuracy rate of 92,5 % with his stepwise multiple discriminant method.

The Springate model is as follows:

$$Z = 1{,}03X1 + 3{,}07X2 + 0{,}66X3 + 0{,}4X4, \qquad \text{(e.g. 2)}$$

Where
X1 = Working Capital / Total Assets
X2 = Net Profit Before Interest and Taxes / Total Assets

X3 = Net Profit before Taxes / Current Liabilities
X4 = Sales / Total Assets

If the value of Z is below 0.862, the possibility of a company’s bankruptcy is high, and the company is considered unstable. Furthermore, Z values below 0.9 should be considered as signals to start paying serious attention to company´s financial condition.

2.3.3 Ohlson’s O-score Model (1980)

Another popular bankruptcy prediction model is the O-score model of Ohlson (1980). Ohlson (1980) was one of the first researcher who criticized Altman and other previous researchers that used the MDA method and came up with his own model based on a statistical method called logistic regression. This method is an alternative to Fisher's (1936) classification method, linear discriminant analysis and is therefore related to Altman’s Z-score model (Gareth et al., 2014). According to Tabachnick & Fidell (1996) “Logistic regression allows one to predict a discrete outcome such as group membership from a set of variables that may be continuous, discrete, dichotomous, or a mix.” Therefore, the logistic regression may be better suitable for cases when the dependent variable is dichotomous such as yes/no, pass/fail and bankrupt/non-bankrupt (Ohlson, 1980, Tabachnivk and Fidell 1996).

Ohlson (1980) chose the methodology of conditional logit analysis to avoid some fairly well-known problems associated with multiple discriminant analysis (MDA). Ohlson (1980) highlighted several problems with the MDA studies, which were also extensively discussed by Eisenbeis (1977) and Tollefson (1975). In short, the criticism of Ohlson (1980) to the MDA method as used by Altman (1968) were:

1. There are two statistical requirements (key assumptions) imposed on the distributional properties of the predictors. First requirement is equal variance-covariance of the explanatory variables for the bankrupt and non-bankrupt firms and the second requirement is normally distributed predictable. According to Ohlson (1980) such requirements are hard to meet up and therefore the reliability and validity when using the MDA method may be doubtful.
2. The output of the MDA model is a score which has little intuitive interpretation, therefore it

is basically an ordinal ranking device (Ohlson, 1980).
3. Bankrupt and non-bankrupt firms are matched according to criteria such as size and industry, and these tend to be somewhat arbitrary. According to Ohlson (1980) variables should be included as predictors rather than to use them for matching purposes.

Ohlson (1980) stated that the use of conditional logit analysis, on the other hand, essentially avoids all of the above problems with respect to MDA. The logit function is suitable to model the probability of bankruptcy because the dependent variable has only two categories (bankrupt or nonbankrupt). The logit function maps the value to a probability bounded between 0 and 1. Furthermore the fundamental estimation problem can be reduced by using the following statement: "What is the probability that the firm belongs to some pre-specified time period?" (Ohlson, 1980) When using this statement "no assumptions have to be made regarding prior probabilities of bankruptcy and/or the distribution of predictors" (Ohlson, 1980).
In his study, Ohlson analyzed 105 bankrupt companies to 2058 non-bankrupt companies of which all US industrials. The boundaries for the population of the Ohlson (1980) model were restricted by the period (from 1970 to 1976), the equity of the firm (had to be traded on some stock exchange or over-the-counter market) and the firm must be classified as an industrial firm. The data collection started three years prior the date of bankruptcy. The cut-off point used by the original study of Ohlson (1980) is 0.38 because this should minimize the Type I and Type II errors. Concluding Ohlson (1980) came up with a nine-factor linear combination of coefficient-weighted business ratios which are readily obtained or derived from the standard periodic financial disclosure statements provided by publicly traded companies. Two of the factors utilized are widely considered to be dummies (X5 and X8) as their value and thus their impact upon the formula typically is 0. Overall, his results showed that the factors: size, current liquidity and financial structure of a firm have a crucial role in detecting bankruptcy (Ohlson, 1980).

The model of Ohlson (1980) is as follows:

$$O = -1.32 - .407X1 + 6.03X2 - 1.43X3 + .0757X4 - 2.37X5 - 1.83X6 + 0.285X7 - 1.72X8 - .521X9 \qquad \text{(e.g. 3)}$$

Where;

X1 = Size (LOG (Total Assets/GNP Index))

X2 = Debt Ratio (Total Liabilities/Total Assets)

X3 = Working Capital to Total Assets

X4 = Current Liabilities to Current Assets

X5 = Total Liabilities Exceeds Total Assets (OENEG), 1, if net income was negative for the last two years = 0, otherwise.

X6 = Return on Assets

X7 = Funds Provided by Operations to Total Liabilities

X8 = Net Income was Negative for The Last Two Years (INTWO), 1 If net income is negative for last two years, 0 otherwise

Changes in net income will be accounted for by using the following variable:

X9 = Delta Net Income Divided by the Sum of the Absolute Net Income (CHIN)

Ohlson stated that "common sense" suggests that the sign of the coefficients would be as follows:

POSITIVE	**NEGATIVE**	**INTERMEDIATE**
TLTA	SIZE	OENEG
CLCA	WCTA	
INTWO	NITA	
	FUTL	
	CHIN	

Table 1. Sign of the coefficients of the different ratios (adopted from Ohlson, 1980)

Regarding the variables in Ohlson´s (1980) model, he added that OENEG serves as a discontinuity correction for TLTA. "A corporation which has a negative book value is a special case. Survival would tend to depend upon many complicated factors, and the effect of the extreme leverage position needs to be corrected. A positive sign would suggest almost certain bankruptcy, while a negative sign suggests that the situation is very bad indeed (due to TLTA), but not that bad" (Ohlson, 1980).

Ohlson, too, tried MDA technique but the results were somewhat “worse” than those of logit model. Ohlson, however, suggested the test of alternative estimating techniques that could possibly serve as a more powerful discriminatory device than the logit model, hypothesizing that many “reasonable” procedures will lead to results which will not differ too much (Ohlson, 1980). Thus, Ohlson admitted that the logit model is not superior compared to other models and the results from different models supposedly don´t differ that much.

Despite its definite advantages, Ohlson´s logit model (1980) have been criticized in a few studies. Hillegeist et al. (2004) state that there are two econometric problems with the single-period logit approach. First, a sample selection bias that arises from using only one, non-randomly selected observation per bankrupt firm, and second, a failure to model time-varying changes in the underlying or baseline risk of bankruptcy that induces cross-sectional dependence in the data. Furthermore, Hensher and Jones (2007) criticized the logit model because “all parameters are fixed and the error structure is treated as white noise, with little behavioral definition”.

2.4. Market-based bankruptcy prediction models

The market-based models are commonly classified into structural (Merton 1974; Agarwal and Taffler 2008; Hillegeist et al. 2004) and reduced (Jarrow and Turnbull 1995; Duffie and Singleton, 1999) form models. An example of a structural model is Merton model which operationalizing requires several assumptions according to Agarwal and Taffler (2008). From their study: “For instance, as Saunders and Allen (2002: 58-61) point out, the underlying theoretical model (Merton model) requires the assumption of normality of stock returns. It also does not distinguish between different types of debt and assumes that the firm only has a single zero-coupon loan. In addition, it requires measures of asset value and volatility which are unobservable. It is therefore not surprising that the empirical evidence on the performance of market-based models is mixed.”

There is a lack of evidence supporting the use of market-based models in predicting financial distress. However, Agarwal and Taffler (2008) found supporting evidence for the use of market-based models such as Black and Scholes (1973) and Merton (1974) contingent claims approach. They claim that these methodologies include the following benefits compared to accounting-based models: (i) it provides a sound theoretical model for firm bankruptcy, (ii) in efficient markets, stock prices will reflect all the information contained in accounting statements and will also contain information not in the accounting statements, (iii) market variables are unlikely to be influenced by firm accounting policies, (iv) market prices reflect future expected cashflows, and hence should be more appropriate for prediction purposes, and (v) the output of such models is not time or sample dependent (Taffler and Agarwal, 2008). They concluded that neither of the market-based models nor the accounting-ratio based model is a sufficient statistic for failure prediction and both carry unique information about firm failure (Hillegeist et al., 2004 reach the same conclusion with their data).

Hillegeist et al (2004) further state that market-based models have some drawbacks such as the limitations of model's assumptions and the need to back out asset value and volatility. These assumptions can introduce errors and biases into the resulting PB (=probability of bankruptcy) estimates (Hillegeist et al, 2004). Prior research has tested the ability of market variables to predict bankruptcy employing methodologies such as the Black and Scholes contingent claims or option-based approach (Bharath and Shumway, 2008; Hillegeist et al., 2004; Reisz and Perlich, 2007; and Vassalou and Xing, 2004). However, the results obtained from these models (that entail numerous restrictive assumptions) have been controversial.

2.5. Conclusion of the prediction models of the previous literature

As discussed above, the following four econometric/statistical techniques have been intensively used to estimate the bankruptcy prediction model: (i) Logit, (ii) Probit (iii) Linear probability, and (iv) Multivariate discriminant analysis (MDA). However, Altman and Saunders (1997) study regards MDA as leading/dominant technique among all the four statistical methods.

Numerous studies have compared the predictive power of different bankruptcy prediction models in their research. However, the accuracy rate of a single model is always dependent on the sample i.e. results tend to be sample-specific and it's therefore difficult to recommend a model over another. Generalizations are hard to make since the financial ratios and their relative weights are derived from a sample analysis. Furthermore, Agarwal et al. (2008) doubt on the models validity by stating: "accounting statements present past performance of a firm and may or may not be in-formative in predicting the future; convertism and historical cost accounting mean that the true asset values may be very different from the recorded book values; accounting numbers are subject of manipulation by management"; and as Hillegeist et al. (2004) argue that since "accounting statement are prepared on a going concern basis, they are, by design, of limited utility in predicting bankruptcy" (Agarwal et al., 2008). This limitation, however, is in percentage quite moderate and such criticism seems irrelevant. Agarwal & Taffler (2008) compared the accounting-based and market-based prediction models for the first time in the literature. The conclusion of their study is as follows: (i) while the z-score model is marginally more accurate, the difference is statistically not significant, (ii) in a competitive loan market, a bank using the z-score approach would realize significantly higher risk-adjusted revenues, profits, return on capital employed, and return on risk adjusted capital than a bank employing the comparative market-based credit risk assessment approach, and (iii) relative information content tests find that both the z-score and market-based approaches yield estimates that carry significant information about failure, but neither method subsumes the other (Agarwal & Taffler, 2008). To summarize, each model´s predictive power differs in relation to the sample data and one cannot generalize the accuracy rate of any of the models based on a single study.

3 DATA AND METHODOLOGY

In this chapter the methods used in this study are presented. The purpose is to show how the data has been collected and analyzed and what methods have been used to get the results.

3.1. Research Methodology

This study aims to compare three accounting-based bankruptcy prediction models of Springate (1978), Ohlson (1980) and Altman (2000). In the following chapters the accuracy rate of these three accounting-based bankruptcy prediction models is compared and analyzed for US manufacturing companies. The accuracy rate is the percentage of correct classification (bankrupt or non- bankrupt) to the total classification (see e.g. Altman (1968), Ohlson (1980) and Zmijewski (1984). Two types of classification errors are made, type I error occurs when failed company is classified as healthy and type II error when healthy company is classified as distressed (Altman, 1968).

In order to answer the research question: “What is the accuracy rate of accounting-based bankruptcy prediction models of Altman (2000), Ohlson (1980), Springate (1978) to US manufacturing companies 1990-2018”? a comparative case study is executed. The classification periods used are t-1, t-2 and t-3 (prior to bankruptcy). This time frame is set because the literature of the selected bankruptcy prediction models claim that they perform best one, two, and three years in advance (see e.g., Ohlson (1980), Zmijewski (1984) and Hussain et al., (2014)).

The results of the study will give answer to the research question. In order to evaluate the accuracy rate of the models of Altman (2000), Ohlson (1980) and Springate (1978), two-way ANOVA test is used to determine whether the models statistically significant differ from each other. In determining, whether the Altman (2000) model will outperform the models of Ohlson (1980) and Springate (1978) a goodness-of-fit test of deviance, or -2 log-likelihood test is adopted.

3.2. Sample selection

The data sample of the study consists of US manufacturing companies that were derived from the COMPUSTAT database with SIC- codes 2000-3999. For defining bankruptcy, chapter 11 and 7 are adapted, which are represented by delisting code 2 (bankruptcy) and 3 (liquidation), respectively. Also, leveraged buyout (1982 forward) which is represented by delisting code 6 and now a private company that is represented by delisting code 9 were allowed in order to increase the sample size of the bankrupt (=1) companies. The subjects are bankrupt and non-bankrupt companies in North America listed on New York Stock Exchange (NYSE), American Stock Exchange (AMEX) and National Association of Securities Dealers Automated Quotation (NASDAQ). Exchange codes for NYSE, AMEX and NASDAQ are 11,12 and 14, correspondingly.

The time period of data spans from 1990 to 2018. In the data collection of bankrupt companies, the last 5 years bankrupt data ever since. Thus, only 33 manufacturing companies filing a bankruptcy between 1990 and 2018 are remained to be effective samples at last. As for non-bankrupt companies, 414 non-bankrupt manufacturing companies are selected. To be selected in the sample, four years of complete financial data for the most recent fiscal years was required for the non-bankrupt firms.

3.3. Sample description

The final sample of the study consists of 33 bankrupt and 414 active manufacturing companies that are publicly listed in Nyse, Nasdaq or American Stock Exchange. From table 4 we can see that most of the bankrupt companies are listed in Nasdaq.

Criteria		Value
Status		Active, Bankrupt, Liquidated, Now a Private Company, Leveraged Buyout
Country		United States
Size		Publicly Listed Companies (Stock Exchange: Nyse, Nasdaq, American Stock Exchange
Investigation period		1990-2018
SIC-code		2000-3999

Table 3. Population for the study

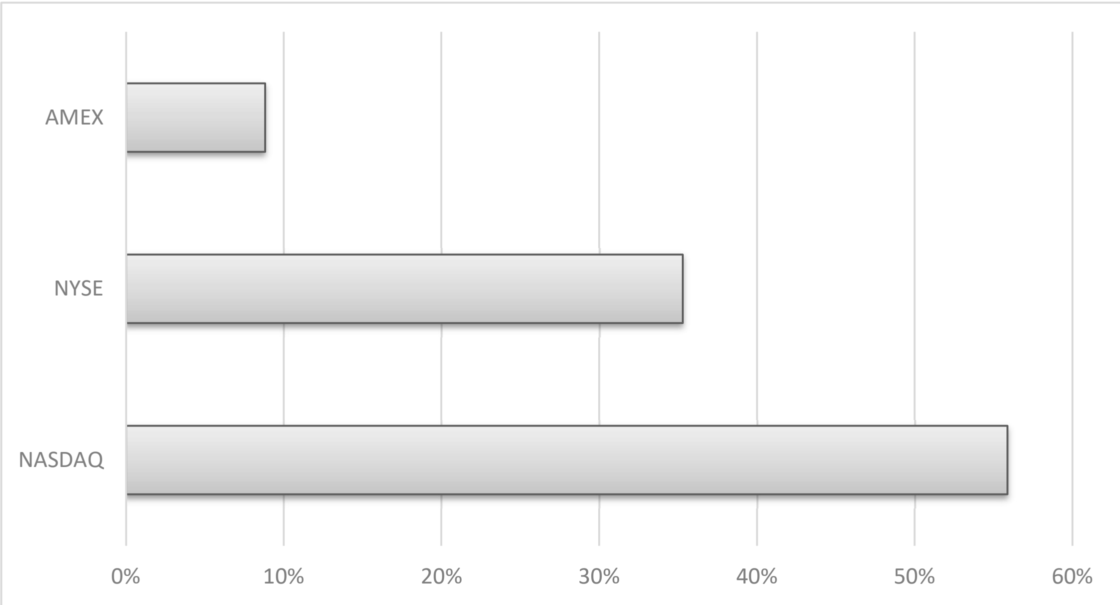

Table 4. Bankruptcy by exchange market

3.4. Research Tools

Numerous of financial prediction models in terms of variables and techniques have been evaluated to investigate which variables and models perform best in predicting financial distress. This study aims to compare three accounting-based bankruptcy prediction models to

US manufacturing companies. The accuracy rate of the models is compared and analyzed through statistical comparative methods. All the statistical analysis is carried out by using the statistical software SPSS.

The models were chosen after survey of previous literature and on the basis of their applicability to the sample of this study and popularity in previous literature. Eventually, the following three models were selected to the study:

1. Altman's (2000) multiple discriminant analysis; also called revisited Z-score model.
2. Ohlson's (1980) logit regression analysis; also called O-score model.
3. Springate's (1978) model, stepwise multiple discriminant analysis; also called S-Score model.

In the following chapters the accuracy rate of these three accounting-based bankruptcy prediction models is compared and analyzed. To determine which of the three models perform best in predicting bankruptcy in US manufacturing companies, analytical quantitative research methods are adopted.

3.5. Accuracy Testing of Prediction Models.

Prediction power or accuracy testing of bankruptcy prediction models is usually based on the classification capability of the model. The classification capability of a certain model is simply measured as a percentage figure of correctly and incorrectly classified companies. The most critical concept of such methods is the determination of the cut-off point which is used as a discriminatory factor. In MDA models (multivariate discriminant model) the cut-off point is presented as a score number. Below is a table that presents the basic setting where the classification capability of a model is evaluated.

	Predicted Group Membership	
Actual Group Membership	Bankrupt	Non-Bankrupt
Bankrupt	Correct prediction	Type I error
Non-Bankrupt	Type II error	Correct prediction

Table 5. Type I and Type II error

Testing the model for type I and type II errors is one way to test model´s ability to correctly classify firms. A model can be inaccurate through two different ways, these mistakes are known as type I or type II errors. A type I error occurs when the model incorrectly predicts a bankrupt company to survive, whereas a type II error occurs when the model predicts a surviving company to go bankrupt (Altman 1968, Verbeek 2012). The study of Altman (1968) is the most famous study that used these two error types to classify the mishits made by a prediction model.

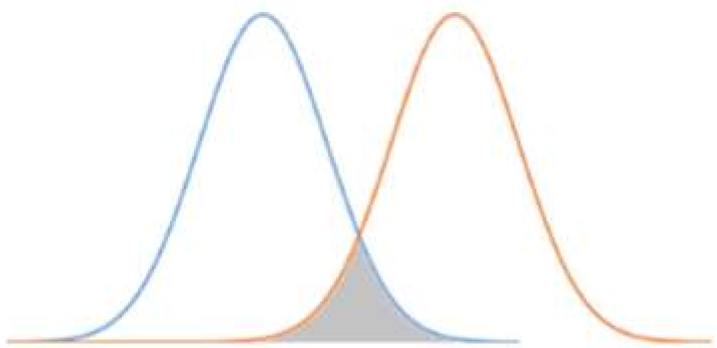

Figure 1. Distributions of multivariate discriminant analysis scores (Adopted from Saastamoinen, 2015)

The purpose of the figure 1 is to provide the reader an understanding of the distributions of the scores of multivariate discriminant analysis. The determination of a "cut-off" point in the MDA is usually done in a way where two distributions, representing estimated scores of bankrupt and non-bankrupt companies, are projected on an axis (see Figure 1 above). After that the overlapping (the gray area in Figure 1) of these distributions is investigated (Saastamoinen, 2015). The grey area consists of scores that fell between the critical value and the "Safe" Zone.

From the figure 1 one can see the three zones of discrimination; the “safe” zone (values on the left side of the gray area), the “gray” zone and the “distress” zone (values on the left side of the gray area). In Altman´s (1968) classic study, the procedure to select a “cut-off” point or optimum Z-value is as follows: (i) identify sample observations which fall within the overlapping area (gray area in figure 1), (ii) the range of values of Z that results in the minimum number of misclassifications is found and (iii) choose the best critical value that discriminates best between bankrupt and non-bankrupt firms (Altman, 1968). In this study, the cut-off points of the models are set to the same levels as in the original studies.

A brief summary of each model used in this study is presented in the Table below

Model	***Formula***	***Variable***	***Description***
Altman (2000) Multiple-Discriminant Analysis	Z = 1.2X1 + 1.4X2 + 3.3X3 + 0.6X4 + 1.0X5 Cut-off Points: Z > 1.81 – Safe Zone Z < 1.81 – Distress Zone The cut-off point is set at 1.81 as in the original study by Altman (2000) which resulted in the lowest overall error in the original tests.	X1 X2 X3 X4 X5	Working Capital / Total Assets Retained Earnings / Total Assets Earnings before interest and taxes / Total Assets Market value of equity / Total Liabilities Sales / Total Assets

Springate (1978) Step wise Multiple Discriminant Analysis	Z = 1.03A + 3.07B + 0.66C + 0.4D Cut-off point: Z < 0.862; firm is classified as Failed Z> 0.862; firm is classified as Healthy Cut-off point is set at 0.862 as in the Springate´s (1978) original study.	X1 X2 X3 X4	Working Capital / Total Assets Net Profit Before Interest and Taxes / Total Assets Net Profit Before Taxes / Current Liabilities Sales / Total Assets
Ohlson (1980) Logit Model	O = -1.32 - .407X1 + 6.03X2 - 1.43X3 + .757X4 - 2.37X5 - 1.83X6 + .285X7 - 1.72X8 - .521X9 X1 = OSIZE X2 = TL/TA P = (1 + exp{- β'X})-1, where P is the probability of bankruptcy and X represents the variables listed. The logit function maps the value of β'X to a probability bounded between 0 and 1. Cut-off point: Safe Zone; O-Score < 0.38 Distress Zone; O-Score > 0.38 In this study the cut-off point is set at 0.38 as in the original study by Ohlson (1980).	X1 X2 X3 X4 X5 X6 X7 X8 X9	Size (LOG (Total Assets/GNP Index)) Total Liabilities/Total Assets Working Capital/Current Assets Current Liabilities/Total Assets Net Income was Negative for The Last Two Years (INTWO) Net Income/Total Assets Fund From Operations/Total Liabilities Total Liabilities Exceeds Total Assets (OENEG) Delta Net Income Divided by the Sum of the Absolute Net Income (CHIN)

Table 4. Summary of empirical models used in the study. In the first column the models

investigated in this study are presented. In the second column the model specifications are summarized and the cut-off points used in this study presented. The final column shows the explanatory variables of each model.

3.6. Derivation of hypotheses

The original studies show that the accuracy rate of Altman (2000), Ohlson (1980), and Springate (1978) are all very high in the original samples. The question that arises is whether there is a difference towards the results of the bankruptcy prediction models of Altman (2000), Ohlson (1980) and Springate (1978) for the Unites States manufacturing industry.

Many studies have tested the applicability of the accounting-based bankruptcy prediction models to different industries and geographical locations. In all these studies the firm characteristics varies regarding at least the size, country, legal status and industry. The generalizability of the accounting-based bankruptcy models has been popular trend among the researchers. The studies where the accuracy rate of the accounting-based models was tested include studies of Wu et al. (2010), Grice and Ingram (2001) and Grice and Duncan (2003). The results of these studies show that the accuracy rate of the models varies in different industries and overall when the firm characteristics (e.g. industry, country) differ. Grice and Dugan (2003) reached an overall accuracy for the X-score (Zmijewski model) and Y-score (Ohlson model) models range from 85.7 to 86.1% and 88.1 to 88.7%. Grice and Ingram (2001) reached and overall correct classification rate of only 57.8% for Altman´s model for their 1988-1991 sample.

Since the models of this study use different financial ratios, it can be assumed that there is a difference in the accuracy rates. However, in the previous literature no consensus exists whether one model performs better than another in general. Since the results are sample specific it's difficult to draw conclusions about the superiority of a particular model. For example, the study of Avenhuis (2013) resulted to suggest that Altman (1968) model performs better than Ohlson (1980) whereas the study of Kleinert (2014) came to conclusion that Ohlson´s (1980) logit model performed better than the model of Altman (1968). Similar contradictory results are presented by a number of studies.

In the following section the hypotheses of the study are presented. The aim of hypothesis testing is to show statistical significance for the difference in the accuracy rate between the models of Ohlson (1980), Springate (1978), and Altman (2000) regarding the United States manufacturing industry.

Also, the alternative hypothesis is tested to see whether the model of Altman (2000) performs better than the models of Ohlson (1980) and Springate (1978). Because of the contradictory results of the previous literature regarding the accuracy rates, it´s interesting to see how the models rank in this study.

On the basis of the previous literature and discussion the following hypotheses were derived and will be tested:

Hypothesis 0 (null hypothesis)

H0: There is no difference in the accuracy rate of the accounting-based bankruptcy prediction models Ohlson (1980), Springate (1978), and Altman (2000) regarding the United States manufacturing industry.

Hypothesis A (alternative hypothesis)

HA: The Z model of Altman (2000) will outperform the models of Ohlson (1980) and Springate (1978) regarding the United States manufacturing industry.

3.7. Criteria for hypotheses testing

To test the hypotheses, a criteria for testing must be set. First, the level of significance is set. “The level of significance is a key input into hypothesis testing. It controls the critical value and power of the test, thus having a consequential impact on the inferential outcome. It is the probability of rejecting the true null hypothesis, representing the degree of risk that the researcher is willing to take for Type I error" (Jae, 2015). In this study, the level of significance is set at 5 %. This means that the null hypothesis can be rejected, when assumed to be true, if the probability of p is less or equal to 5 %.

		BANKRUPT FIRMS t-1 (N=33)			NON-BANKRUPT FIRMS t-1 (N=414)			BANKRUPT FIRMS t-2 (N=33)			NON-BANKRUPT FIRMS t-2 (N=414)			BANKRUPT FIRMS t-3 (N=33)			NON-BANKRUPT FIRMS t-3 (N=414)		
Ohlson (1980)		***MEAN***	***MEDIAN***	***STD. DEV.***	***MEAN***	***MEDIAN***	***STD. DEV.***	***MEAN***	***MEDIAN***	***STD. DEV.***	***MEAN***	***MEDIAN***	***STD. DEV.***	***MEAN***	***MEDIAN***	***STD. DEV.***	***MEAN***	***MEDIAN***	***STD. DEV.***
	LOG SIZE	3.067	2.896	0.690	3.125	3.145	0.866	3.070	3.040	3.034	3.083	3.092	0.866	2.999	2.967	2.961	3.000	3.022	0.906
	TL/TA	0.458	0.481	0.230	0.469	0.393	0.366	0.436	0.433	0.441	0.469	0.406	0.415	0.466	0.465	0.475	0.605	0.414	2.144
	WC/CA	0.482	0.516	0.293	0.566	0.696	0.429	0.515	0.515	0.508	0.552	0.706	0.464	0.486	0.485	0.476	0.569	0.678	0.425
	CL/TA	0.314	0.259	0.194	0.245	0.185	0.217	0.284	0.287	0.291	0.253	0.185	0.288	0.301	0.303	0.308	0.350	0.192	1.638
	INTWO	0.000	0.000	0.000	0.053	0.000	0.224	0.000	0.000	0.000	0.043	0.000	0.204	0.030	0.031	0.032	0.068	0.000	0.251
	NI/TA	-0.028	0.014	0.166	-0.292	-0.066	0.576	0.001	-0.001	-0.003	-0.296	-0.092	0.676	-0.044	-0.047	-0.051	-0.385	-0.094	1.087
	FU/TL	0.217	0.015	0.697	0.355	0.081	2.596	0.038	0.036	0.030	0.300	0.086	0.731	0.084	0.086	0.088	0.348	0.072	1.129
	OENEG	0.333	0.000	0.471	0.563	1.000	0.496	0.364	0.375	0.386	0.568	1.000	0.495	0.394	0.406	0.419	0.553	1.000	0.497
	CHIN	-0.076	-0.077	-0.048	0.000	0.000	0.000	-0.083	-0.079	-0.086	0.000	0.000	0.000	-0.141	-0.146	-0.138	0.000	0.000	0.000
Altman (2000)	**W/TA**	0.398	0.404	0.404	0.298	0.281	0.236	0.432	0.437	0.435	0.293	0.287	0.270	0.399	0.402	0.397	0.224	0.296	1.173
	RE/TA	-0.985	-1.049	-1.106	-2.575	-0.599	5.430	-0.792	-0.851	-0.904	-2.454	-0.543	5.394	-0.689	-0.744	-0.795	-2.591	-0.659	5.129
	EBIT/TA	0.065	0.059	0.059	-0.843	-0.125	1.708	0.065	0.056	0.049	-0.805	-0.197	1.749	-0.020	-0.033	-0.037	-1.075	-0.240	2.946
	BE/TL	1.697	1.736	1.726	1.338	0.594	2.085	2.601	2.672	2.669	1.298	0.615	2.034	0.938	0.946	0.875	1.296	0.649	2.207
	SALES/TA	1.006	1.001	0.995	0.627	0.562	0.606	0.954	0.950	0.957	0.632	0.551	0.601	0.998	0.997	1.005	0.669	0.524	0.659
Springate (1978)	**WC/TA**	0.197	0.203	0.209	0.416	0.412	0.329	0.164	0.169	0.174	0.408	0.401	0.376	0.076	0.078	0.080	0.312	0.392	1.636
	EBIT/TA	0.065	0.059	0.059	-0.271	-0.077	0.550	0.065	0.056	0.049	-0.259	-0.063	0.563	-0.020	-0.033	-0.037	-0.346	-0.040	0.948
	EBT/CL	-0.021	-0.029	0.014	-1.745	-0.661	2.927	-0.142	-0.156	-0.177	-1.881	-0.891	2.778	-0.166	-0.186	-0.205	-2.212	-0.839	3.836
	SALES/TA	1.006	1.001	0.995	0.628	0.525	0.607	0.954	0.950	0.957	0.633	0.552	0.602	0.998	0.997	1.005	0.670	0.563	0.660

Table 6. Summary statistics for explanatory variables. This table reports summary statistics for all of the required accounting ratios for the bankrupt and non-bankrupt firms t-1, t-2 and t-3 years prior to bankruptcy.

4 EMPIRICAL RESULTS

This chapter presents the findings of the statistical tests used to evaluate the accounting-based bankruptcy prediction models. The section starts with analysis of the descriptive statistics, followed by individual analysis of the models. Next, the results are compared to previous studies and then the significance test for the possible difference in the predictive power of the models is tested.

4.1. Univariate analysis of the sample

Similar to many previous studies (e.g. Shumway, 2001) the analysis of the data starts with descriptive statistics. The table 6 contains all the descriptive statistics for the bankrupt and non-bankrupt firms one, two and three years prior to bankruptcy (for the non-bankrupt group, three most recent financial years). The reason for summarizing the descriptive statistics is to compare the different variables and to observe differences between bankrupt and non-bankrupt firms.

When comparing the variables between bankrupt and non-bankrupt firms, the first impression is that the main statistical values are, in average, lower for the bankrupt firms than for the healthy firms. In general, the scores for healthy firms are positive, which is in line with few other studies like Kleinert (2014) and Avenhuis (2013). For the distressed firms, a total of 8 variables have at least one negative score in the research period. The negative variables are listed in the table 7 below and discussed more in-depth later in this chapter.

Compared to some previous studies (e.g. Gerritsen, 2015 and Boritz et al., 2007) the differences in variables between healthy and distressed firms are quite moderate. Further comparison of the variables shows that, in general, the non-bankrupt firms have slightly better financial situation in terms of liquidity, profitability and leverage. For variables TL/TA, WC/CA and FU/TL the scores are higher for non-bankrupt companies for all investigation periods which indicates a better financial situation for the healthy group.

4.2.Analysis of negative variables

The number of negative variables for bankrupt firms in the sample is described in the table below. In total, 7 of 18 variables showed negative scores for bankrupt firms. For the variables NI/TA, RE/TA, EBIT/TA and EBT/CL the number of negative variables is notably high for t-1, t-2 and t-3-time frames (year prior to bankruptcy). It can be seen from the table 7, that in general the percentual number of negative variables is highest one year prior to bankruptcy for the three variables NI/TA, RE/TA, and EBT/CL that show the highest number of negative variables for the bankrupt firms. In conclusion, the bankrupt firms show clear evidence of the distress.

Variable	t-1 (N=33)	t-2 (N=33)	t-3 (N=33)
Negative WC/CA	3.0 %	9.10 %	9.10 %
Negative WC/TA	3.0 %	9.09 %	9.09 %
Negative NI/TA	**42.4 %**	**36.36 %**	**39.39 %**
Negative FU/TL	15.2 %	15.15 %	12.12 %
Negative RE/TA	**36.4 %**	**36.36 %**	**27.27 %**
Negative EBIT/TA	**27.3 %**	**30.30 %**	**33.30 %**
Negative EBT/CL	**45.45 %**	**39.39 %**	**36.36 %**

Table 7. Statistics of the negative variables for the distressed firms

4.3. Analysis of the bankruptcy prediction models

In table 8, the overall performance of all three models is presented. It is exciting to see that the model of Altman (2000) outperforms the models of Ohlson (1980) and Springate (1978) in the number of correct classifications for both type of companies, failed and non-failed in all time frames (years prior to bankruptcy). Like many previous studies (e.g. Anjum, 2012 and Kleinert, 2014), the accuracy rates in general tend to decrease as the years prior to bankruptcy increase. However, as can be observed from the table 8 no such pattern is present for the US manufacturing firms. From the table it can be concluded that Altman´s (2000) model makes most precise distinctions between bankrupt and non-bankrupt companies and the classification rate is quite flat in the investigation years t-1, t-2 and t-3 prior to bankruptcy.

	Bankrupt Firms			Non-bankrupt Firms		
	t-1 (N=33)	**t-2 (N=33)**	**t-3 (N=33)**	**t-1 (N=414)**	**t-2 (N=414)**	**t-3 (N=414)**
Altman (2000)	90.91 %	84.85 %	87.88 %	86.23 %	87.92 %	88.65 %
(Error- %)	9.09 %	15.15 %	12.12 %	13.77 %	12.08 %	11.35 %
Ohlson (1980)	60.61 %	63.64 %	63.64 %	48.79 %	49.52 %	53.14 %
(Error- %)	39.39 %	36.36 %	36.36 %	51.21 %	50.48 %	47.86 %
Springate(1978)	69.70 %	72.73 %	54.55 %	34.54 %	31.88 %	34.51 %
(Error- %)	30.30 %	27.27 %	45.45 %	65.46 %	68.12 %	64.49 %

Table 8. Prediction Accuracy of the models

4.3.1. Analysis of the Altman (2000) model

The results for the Type I and Type II errors of the models one year prior to bankruptcy (t-1) are presented in tables 9,10 and 11. As discussed earlier, Type I error occurs when the observed firm is bankrupt firm but predicted non-bankrupt and Type II error when the observed firm is non-bankrupt firm but predicted as bankrupt firm.

The results for Altman´s (2000) model one year prior to bankruptcy are presented in the table 9. The per cent chance of Type I error is 9,09 and Type II error 13.77. The results suggest that the model of Altman (2000) is accurate in both categories and have good predicting ability for US manufacturing companies. The model shows accuracy two and three years prior to bankruptcy as can be observed from table 8. There is no trend suggesting degrading forecast accuracy and the model performs almost evenly for all three periods prior to bankruptcy.

	Altman (2000)		
Actual	Bankrupt	Non-Bankrupt	Total
Bankrupt	30	3	33
Non-Bankrupt	57	357	414
Total	87	360	447

	Number Correct	**Per Cent Correct**	**Per Cent Error**	**n**
Type I	30	90.91	9.09	33
Type II	357	86.23	13.77	414
Total	387	86.58	13.42	447

Table 9. Type I and Type II errors one year prior to bankruptcy for Altman´s (2000) model

4.3.2. Analysis of the Ohlson (1980) model

The results of the Ohlson (1980) logit model one year prior to bankrupt are presented in the table 10 below. The results suggest that the model performs much worse than the model of Altman (2000) when predicting bankruptcy in US manufacturing companies. The per cent chance of Type I error is 39.39 and Type II error 51.21. The results show that Ohlson (1980) model has no predicting ability to non-bankrupt US manufacturing firms as the correctness of the prediction has a base chance of 50/50. Other studies have shown significantly better results for Ohlson (1980) model (e.g. Avenhuis, 2013 and Kleinert 2014). The predicting accuracy for two and three years prior to bankruptcy is quite similar compared to one-year prior bankruptcy and no trend suggesting degrading accuracy is noticeable.

	Ohlson (1980)		
Actual	Bankrupt	Non-Bankrupt	Total
Bankrupt	20	13	33
Non-Bankrupt	212	202	414
Total	232	215	447

	Number Correct	Per Cent Correct	Per Cent Error	n
Type I	20	60.61	39.39	33
Type II	202	48.79	51.21	414
Total	232	49.66	50.34	447

Table 10. Type I and Type II errors one year prior to bankruptcy for Ohlson (1980) model

4.3.3. Analysis of the Springate (1978) model

The table 11 shows the accuracy rates for the Springate (1978) model. The per cent chance of Type I error is 30.30 and Type II error 65.46. Thus, for the non-bankrupt group, the model has no predicting ability. The Type I error rate is also quite high, although the results suggest that the model has some predicting ability when classifying the bankrupt firms. What´s interesting compared to other two models is the big variation of accuracy rate for the bankrupt group. From table 8 we can observe that the accuracy rate fluctuates from 54.55% (t-3) to 72.73% (t-2). We can conclude that the model of Springate (1978) significantly loses forecast accuracy three years prior to bankruptcy.

	Springate (1978)		
Actual	Bankrupt	Non-Bankrupt	Total
Bankrupt	23	10	33
Non-Bankrupt	271	143	414
Total	294	153	447

	Number Correct	Per Cent Correct	Per Cent Error	n
Type I	23	69.70	30.30	33
Type II	143	34.54	65.46	414
Total	166	37.14	62.86	447

Table 11. Type I and Type II errors one year prior to bankruptcy for Springate´s (1978) model

The results suggest that Altman´s (2000) Z- model is most accurate in classifying firms in both categories. The model has remarkably better predicting ability to US manufacturing companies than the other two models measured in the study. Based on the accuracy rates observed the model of Altman (2000) shows applicability to US manufacturing industry and can be suggested over the models of Ohlson (1980) and Springate (1978) for manufacturing industry.

4.4. Comparison of the results to previous literature

To assess the goodness of the results of this study, one needs to compare the accuracy rates observed to other similarly conducted studies in the literature. The table below collates accuracy rates observed in other studies one year prior to bankruptcy.

Accuracy rate observed t-1

Studies	Altman (1968)	Altman (2000)	Ohlson (1980)	Springate (1978)
Altman (2000)		94.00%		
Kleinert (2014)	68.30 %		97.40 %	
Talebnia et al. (2016)				69.00 %
Imelda. Adolia (2017)	63.00 %		65.00 %	
Own Study		90.91 %	60.61 %	69.70 %

Table 12. Overview of accuracy rates observed in the different time frames from similar research

From the table, we can conclude that the accuracy rates for Altman (2000) and Springate (1978) are in line with previous studies, and for Ohlson (1980) the score is lower than in other studies. Interestingly, the accuracy rate of Altman (2000) model is near to that of the original study and it seems that the applicability of this model is relatively good for US manufacturing industry.

4.5. Hypothesis testing

As discussed earlier the following hypothesis were formulated and will be tested:

Hypothesis 0 (null hypothesis)

H0: There is no difference in the accuracy rate of the accounting-based bankruptcy prediction models Ohlson (1980), Springate (1978), and Altman (2000) regarding the United States manufacturing industry.

Hypothesis A (alternative hypothesis)

HA: The Z model of Altman (2000) will outperform the models of Ohlson (1980) and Springate (1978) regarding the United States manufacturing industry.

In testing the hypotheses, the statistical program SPSS is used. First, a two-way ANOVA can be applied. Table 13 shows the differences between the models and within the models. The results imply that the models statistically significant (.000 for t-1, .002 for t-2, .019 for t-3 and .000 overall) differ from each other regarding the US manufacturing industry. Anova is a statistical tool used to detect differences between experimental group means. (Sawyer, 2009).

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	22.94861	17	1.349918	15.55693	**1.87E-07**
Within Groups	1.56191	18	0.086773		
Total	24.51052	35			
Between Groups	24.34535	17	1.432079	11.43871	**2.09E-06**
Within Groups	2.253526	18	0.125196		
Total	26.59888	35			
Between Groups	20.8128	17	1.224282	17.97902	**5.83E-08**
Within Groups	1.225711	18	0.068095		
Total	22.03851	35			

Table 13. Results two-way ANOVA

Since the results show that the models statistically significant (.000 for t-1, .000 for t-2, .000 for t-3 and .000 overall) differ from each other regarding the US manufacturing companies, the null hypothesis that there is no difference in the accuracy rate between the accounting-based bankruptcy prediction models of Altman (2000), Ohlson (1980) and Springate (1978) can be rejected.

In testing the alternative hypothesis, the deviance, or -2 log-likelihood test is used. The deviance statistic can be used when we need to ascertain how good our regression model is once we have fitted it to the data. The question is whether our predictor variables make a dependable difference to the accuracy of the equation. The deviance is a measure of goodness-of-fit and was first proposed by Nelder and Wedderburn in 1972. It compares the difference in probability between the predicted outcome and the actual outcome for each case and sums these differences together to provide a measure of the total error in the model. The higher the value the less accurate the model, i.e. higher values indicate poorly fitting models and low values better fit. The deviance should be reduced every time we add variable to our model and the lower the deviance ends up after adding all variables, the better the model.

In SPSS, the Omnibus test can be used to check that the new model (with explanatory variables included) is an improvement over the null model that just includes the response variable. The test is called Goodness-of-Fit, i.e., how well the model predicts results, and how well this model accurately predicts the risk of a company (Pallant, 2011). The time frame for comparing the models is t-1, one year prior to bankruptcy. The results of the tests are in the tables 14,15 and 16.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	20.106	5	0.001
	Block	20.106	5	0.001
	Model	20.106	5	0.001

Table 14. Omnibus Tests of Model Coefficients t-1 Altman (2000)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	44.236	8	0.000
	Block	44.236	8	0.000
	Model	44.236	8	0.000

Table 15. Omnibus Tests of Model Coefficients t-1 Ohlson (1980)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	40.485	4	0.000
	Block	40.485	4	0.000
	Model	40.485	4	0.000

Table 16. Omnibus Tests of Model Coefficients t-1 Springate (1978)

The Sig. values for all models are $p < .001$, which indicates the accuracy of the model improves when we add our explanatory variables. The Model row in the tables is the one that compares the new model over the baseline model.

From the tables 14,15 and 16 we can see that the results are consistent with the accuracy rates of the models that were analyzed earlier in the study. The lowest score for the deviance or -2 log-likelihood can be found for Altman´s (2000) model, 20.106. Equivalent scores for Ohlson (1980) and Springate (1978) model are 44.236 and 40.485, indicating that the models are poorly fitting compared to the model of Altman (2000). The results were expected as the

Altman´s (2000) model performed substantially better than the model of Ohlson (1980) and Springate (1978) regarding its accuracy rate to US manufacturing companies.

Based on the results of the deviance, or -2 log-likelihood (-2LL) statistic, the alternative hypothesis can be rejected as the -2LL statistic scores shows clear indications of the better fit of the Altman (2000) model compared to the models of Ohlson (1980) and Springate (1978). We can conclude that there is a statistically significant difference in the performance of the models in favor of Altman´s (2000) model.

5 CONCLUSION AND DISCUSSION

This study examined the predictive power of accounting-based bankruptcy prediction models of Altman (2000), Ohlson (1980) and Springate (1978) to US manufacturing companies. In this section the main findings of the Thesis are presented. Also, the limitations of the study follow after conclusions. Finally, the suggestions for future research are presented.

5.1. Conclusion of findings

This paper compared the performance of three accounting-based bankruptcy prediction models of Altman (2000), Ohlson (1980) and Springate (1978) to US manufacturing companies from 1990-2018. The purpose was to evaluate whether there is difference in the predictive power i.e. the accuracy rate between the models. Based on previous literature, one could expect that the models perform different in their accuracy rates and this was also the outcome of this study.

The main conclusions of the study are that the model of Altman (2000) performs better than the model of Ohlson (1980) and Springate (1978) in US manufacturing companies for both types of firms i.e. the bankrupt and non-bankrupt firms. The results showed that there is difference between the predictive power of the models. The predictive ability of the model of Altman (2000) is substantially better than the models of Ohlson (1980) and Springate (1978) as the mean differences differ greatly in favor of Altman´s (2000) model. The accuracy rates for the models of Altman (2000), Ohlson (1980) and Springate (1978) are 90,91%, 60,61% and 69,70% one-year prior to bankruptcy.

In testing the hypotheses, the results suggested that the model of Altman (2000) performed better than the model of Ohlson (1980) and Springate (1978). The deviance statistic test showed clear indications of the better fit of the model of Altman (2000) as the values for Ohlson (1980) and Springate (1978) were much larger thus indicating poorly fitting models. Also, from the results we could conclude that the models differ with their accuracy rate i.e. their predictive power is different to US manufacturing companies.

What´s furthermore interesting is the capability of Altman´s (2000) model to classify the non-bankrupt firms much better than that of the models of Ohlson (1980) and Springate (1978). Infact, the model of Springate (1978) don´t hold any predicting ability when it comes to classifying the non-bankrupt companies as the accuracy rate is overall just below 35%. The model of Ohlson (1980) have similar results as the predicting accuracy is below 50% and thus a random coin flip would produce better results than the model.

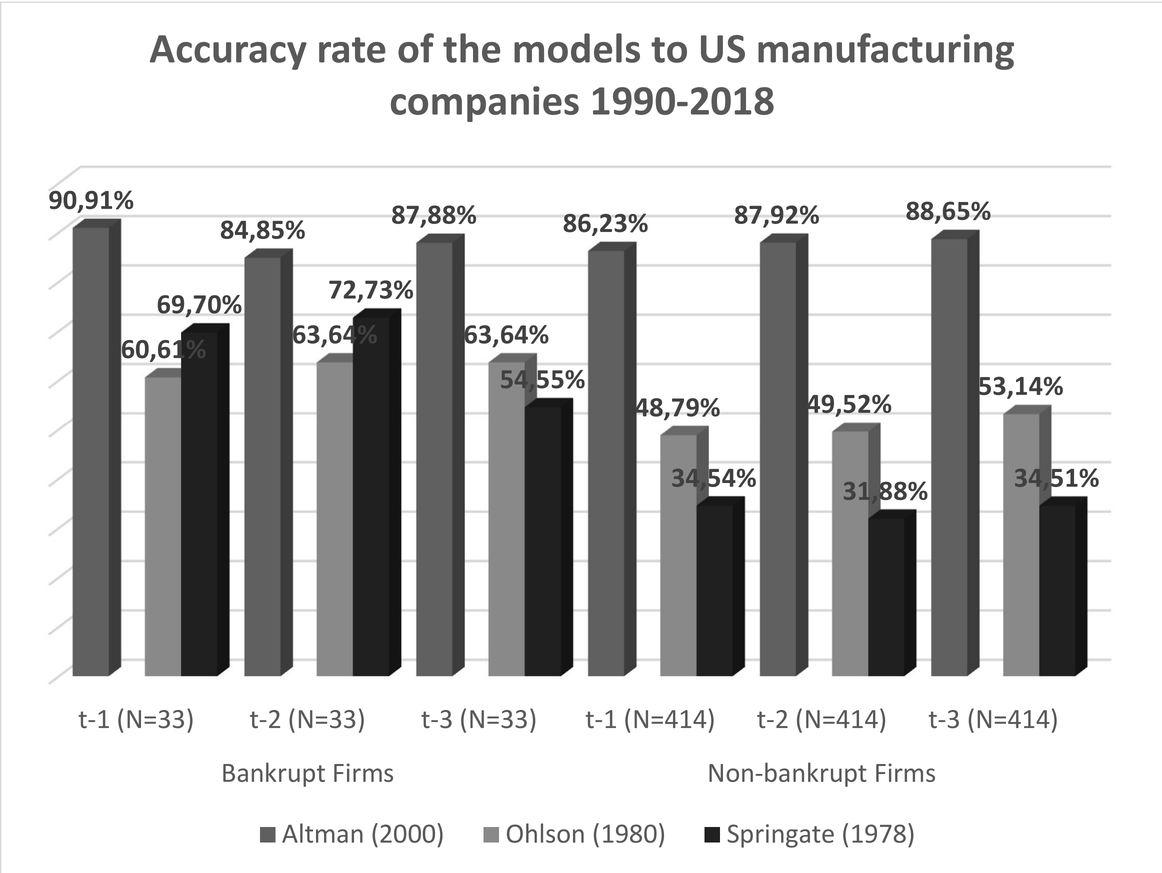

Table 17. Comparison of the accuracy rate of the models of Altman (1968), Ohlson (1980) and Springate (1978) to US listed manufacturing companies

In this study two hypotheses were established to answer the underlying question of the study whether or not there is a difference between accuracy rates of Altman (1968), Ohlson (1980) and Springate (1978). The table 17 summarize the findings of accuracy rate on manufacturing companies. The overall findings of the study show that the accuracy rate of Altman (2000) model is much higher than those of Ohlson (1980) and Springate (1978). Based on the mean differences the Z model performs better than the Ohlson (1980) model and Springate's (1978) model at all time frames (e.g. t-1, t-2, t-3 and overall) as discussed in the previous section of the study. The alternative hypothesis was rejected as the goodness-of-fit test showed clear indications of the better fit of the model of Altman (2000) to US manufacturing industry.

Regarding the accuracy rate, the study found that only Altman´s (2000) model performs well for manufacturing companies. The mean accuracy rate for the model for the three years prior to bankruptcy was 87,88% overall. The two other models, Ohlson (1980) and Springate (1978) model had a mean overall accuracy rate of 62,63% and 65,66% respectively.

5.2. Limitations

This study analyzed and compared three accounting-based bankruptcy prediction models that are commonly studied in the field of research. Accounting-based models holds limitations to themselves and thus, this study has some limitations as well. Agarwal and Taffler (2008) criticized accounting-based bankruptcy prediction models having various limitations. "Accounting-ratio based mostly models are generally designed by looking through an outsized variety of accounting magnitude relations with the ratio weightings calculable on a sample of failing and non-failed firms. Since the ratios and their weightings are derived from sample analysis, such models are likely to be sample specific" (Agarwal and Taffler, 2008). This limitation, however, is not present in this study since the models are not re-estimated. Another limiting circumstance according to their study: "Data are supported historical info and influenced by future trends. Those trends aren't enclosed within the accounting-based bankruptcy models and so accounting-based bankruptcy prediction models are restricted by themselves" (Agarwal and Taffler, 2008).

The sample of this study holds limitations regarding its size and time. The data was retrieved from WRDS database that contains all listed and non-listed US manufacturing companies (SIC-codes between 2000-3999) but the amount of bankrupt companies was still only 33 even though reliefs were given to the data (delisting codes 06 = leverage buyout 1982 forward, = now a private company were allowed) and the time frame was extended to encompass years from 1990 to 2018. Also, similarly to Altman´s (1968) study the sample of this study consists only of manufacturing companies which limits the generalizability of the results because other industries are excluded.

5.3. Outlook for Future research

The study has raised many questions regarding the performance of accounting-based models and their generalizability to different industries. The results of the study suggested that only the Z-model of Altman (2000) performs well for US manufacturing companies. This highlights the fact that in general the generalizability of the models is quite questionable and practitioners should use them cautiously. For future research, a possibility would be to compare the accuracy rate of accounting-based models to market-based models for manufacturing companies in order to assess whether the market-based models hold more predicting power. In this study, the accounting-based models tested had big differences in the predicting power which furthermore suggest the test of other types of models for manufacturing industry.

Also, a more emphasis could be put in research focused on classifying the healthy companies. Traditionally, the focus in research has been in classifying the distressed firms but the question of whether they are of more interest among practitioners is somewhat unclear.

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